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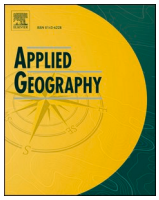

Spatial inequities in urban resource access, neighborhood social capital, and late-life depression: Insights from Hong Kong's aging population

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ABSTRACT

Spatial disparities in urban resources and health outcomes among older adults are well documented, with growing empirical attention to how absolute levels of accessibility affect health. However, less is known about the implications of intra-area inequality in infrastructure access, which may represent an additional form of environmental disadvantage with mental health consequences.

Using data from 5007 older adults aged 50 and above in Hong Kong, we examined how accessibility and within-district inequality of urban facilities are associated with depressive symptoms. Accessibility indicators for four types of urban facilities were calculated for 1746 Large Subunit Groups using an exponential distance-decay model and aggregated to 18 districts. District-level access inequality was measured by Gini coefficient. Principal component analysis was conducted to reduce multicollinearity, yielding two key factors: resource accessibility and resource inequality.

Results from population-weighted linear regressions with district fixed effects reveal that higher resource inequality was associated with more depressive symptoms, whereas higher resource accessibility was associated with less symptoms. Importantly, neighborhood social capital buffered the negative impact of resource inequality, yet did not modify the effect of accessibility.

Our findings highlight a dual pathway linking the urban built environment to late-life mental health: the absolute level of supportive infrastructure reduces depressive symptoms, whereas inequitable spatial allocation increases them. Strengthening neighborhood social capital can mitigate, but not fully offset the psychological burden of structural resource inequality. Creating age-friendly and mentally healthy cities therefore requires integrating distributional justice into infrastructure planning alongside initiatives that foster neighborhood trust and reciprocity.

1. Introduction

Population ageing is reshaping cities worldwide and poses major challenges for mental health. By 2030, one in six people globally will be aged 60 or above, and late-life depression is projected to remain a leading contributor to disability in older adults (WHO, 2023, 2024). At the same time, urban areas are increasingly marked by socio-spatial inequalities in the distribution of services, amenities and opportunities (Tu et al., 2025). Older adults, whose mobility and social networks often shrink with age, are particularly vulnerable to these inequalities and may struggle to access the resources needed to support healthy ageing (Buffel et al., 2012; Gorman, 2020). Hong Kong exemplifies these global dynamics. With 36.0 % of residents expected to be aged 65 or older by 2046 (Census and Statistics Department, 2023) it also ranks among the most unequal developed regions, reflected in a Gini coefficient of about 0.54 in 2016. This combination of rapid ageing and stark inequality in a dense urban environment underscores the importance of understanding how resource accessibility and its unequal distribution affect older adults' mental health.

Person–environment (P–E) fit theory, rooted in Lawton and Nahemow's Press–Competence model (Lawton & Nahemow, 1973), provides a useful lens for understanding how such urban conditions shape late-life mental health. As functional capacity declines, older adults become more dependent on their immediate environment to carry out daily activities and maintain psychological well-being. Fit or misfit arises not only from individual characteristics, but also from the

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availability and accessibility of environmental resources that support everyday life (Motomura et al., 2024; Rambaldini-Gooding et al., 2021). Higher accessibility to urban infrastructures has been associated with better mental health (Zhao et al., 2023). However, focusing on average accessibility alone risks obscuring how these resources are distributed. Spatial inequalities in access can create pockets of relative disadvantage within the same area, with consequences for mental health over and above absolute levels of provision (Chen et al., 2024). Evidence from emerging work on service provision shows that cities with comparable average access can differ markedly in distributional fairness and its health implications (Wu & Tseng, 2018). Yet, few studies have jointly examined both absolute accessibility and access inequality in relation to depressive symptoms among older adults.

At the same time, the mental-health effects of spatial disadvantage in access are unlikely to be uniform. Social capital, commonly indicated by shared trust, reciprocity, and mutual support among neighbors (Putnam, 2001), has been recognized as a key community asset and social determinant of health in later life (Coll-Planas et al., 2016). In more socially cohesive neighborhoods, older adults may compensate for limited formal resources through mutual help, information sharing, and emotional support. Recent evidence from China indicates that social capital can attenuate socioeconomic inequalities in depressive symptoms, suggesting a buffering role (Cao et al., 2022). However, little is known about whether neighborhood social capital buffers the mental-health effects of spatial disadvantage arising from both low absolute accessibility and high inequality in access.

In light of these gaps, this study examines how spatial inequality in access to relevant services relates to depressive symptoms among older adults, using Hong Kong as a case study. We assess both absolute accessibility and within-district inequality in access to four types of services: parks and open spaces, healthcare facilities, public transportation, and elderly service facilities. The selection of these services reflects not only established theoretical perspectives on environmental determinants of healthy ageing but also Hong Kong's contextual realities, where indoor living spaces are relatively crowded and often insufficient to support social and recreational needs. We further explore whether neighborhood social capital moderates these associations. By integrating these elements, the study seeks to fill the noted conceptual gaps and contribute evidence for urban planning and public health initiatives. The findings will inform whether promoting equitable access to age-friendly resources, alongside strengthening neighborhood social fabric, can reduce depressive symptoms and advance environmental justice for ageing populations in Hong Kong and beyond.

2. Literature review

2.1. Spatial accessibility and mental health

Lawton and Nahemow (1973) Press–Competence model and the subsequent P–E fit model highlight that older adults' well-being depends on how well their functional capacities match environmental demands (Perry et al., 2013). Older people rely more heavily on their immediate surroundings to sustain daily functioning and psychological health, making neighborhood characteristics and accessibility especially consequential. A growing body of research shows that access to key built-environment features, such as healthcare services, green areas, and public transport, can significantly influence older adults' mental health (Song et al., 2024; Zumelzu et al., 2025). The World Health Organization's Age-Friendly Cities and Communities (AFCC) further underscores this by identifying eight domains linked to older adults' quality of life (WHO, 2007). Among the domains, outdoor spaces and buildings, transportation, community support and health services, and social participation are particularly tied to urban infrastructure, as they shape older adults' opportunities for mobility, social engagement, and access to everyday services.

The outdoor spaces and buildings domain, for instance, encompasses parks and open spaces that provide opportunities for recreation and social engagement. Substantial evidence indicates that better access to parks and leisure facilities is associated with more physical activity participation and better mental well-being among older adults (Liu et al., 2023; Poppe et al., 2022). Mobility is another critical component of healthy ageing, enabling older people to maintain independence and participate in community life (Hansmann et al., 2024). As people age, mobility often declines due to reduced muscle strength, balance problems, and cognitive changes, making the availability of accessible and reliable transport systems particularly important. Older adults tend to rely more heavily on public transportation than younger groups to meet their daily needs, and reviews suggest that good public transport accessibility positively affects older adults' mental health (Rambaldini-Gooding et al., 2021). Beyond mobility, the ability to build and maintain social relationships is also vital for healthy ageing (WHO, 2023). Participation in community events, cultural activities, and volunteer work can mitigate loneliness and enhance quality of life (Finlay et al., 2024). Organizations such as elderly centers provide venues for such activities and can play an important role in facilitating social participation and promoting well-being (Cannuscio et al., 2003). Access to healthcare services constitutes another key determinant of older adults' well-being; limited availability or difficult access may contribute to poorer health outcomes and greater vulnerability (Spring 2017). Overall, the literature suggests that spatial accessibility to key environmental resources forms a critical foundation of Person-Environment fit in later life, supporting mental health and overall well-being among older adults.

2.2. Inequality in resource access

While absolute access to urban resources is important, uneven distributions of infrastructure and services can create structural advantages and disadvantages between places. The spatial inequality paradigm posits that structural imbalances in infrastructure provision generate geographies of exclusion and privilege, whereby some communities benefit disproportionately from urban resources while others are systematically underserved (Wei, 2015). From this macro-structural perspective, disparities in the spatial distribution of age-relevant facilities including parks, healthcare, transport, and elderly centers may reinforce or widen existing health inequalities (Cheng et al., 2020). A substantial body of research has documented the adverse health consequences of economic inequality. A meta-analysis reported that a 0.05-unit increase in the Gini coefficient of income inequality was associated with a 1.08-fold higher risk of mortality and a 1.04-fold higher likelihood of poor self-rated health (Kondo et al., 2009). Focusing on older populations, a cross-national study of 14 European countries showed that greater income inequality was linked to poorer health in later life (Ploubidis et al., 2012). Similarly, evidence from the United States indicates that spatial income inequality is associated with higher levels of depression among older adults (Muramatsu, 2003).

However, the above literature focused mainly on income disparities. Structural inequalities in environmental and service access have received far less attention, particularly in relation to older adults' mental health. From the urban justice framework (Noll & Bhar, 2023), uneven distributions of healthcare, transport, green space, and other amenities represent a failure in distributive justice that can translate into both practical barriers and psychosocial stress. Yet research on ageing and mental health still tends to emphasize individual socioeconomic status or absolute environmental exposure, with limited attention to how equitably resources are distributed (Gong et al., 2023). Recent scholarship therefore calls for explicitly incorporating equity into evaluations of service provision, recognizing that cities with similar average access may differ markedly in distributional fairness and its health implications (Wu & Tseng, 2018).

2.3. The protective role of social capital

Social capital offers a valuable lens for understanding why the mental-health consequences of spatial resource deprivation and inequality vary across individuals. A growing body of empirical research shows that older adults living in communities with stronger social capital, characterized by a sense of belonging, trust in neighbors, and norms of reciprocity tend to report better psychological well-being (Kim et al., 2020). Such relational resources are integral to "successful ageing, " enabling older adults to maintain independence and emotional resilience even when material or environmental conditions are constrained (Cannuscio et al., 2003). Evidence from China further demonstrates that both family- and village-level social capital can buffer inequalities in depressive symptoms, with the most socioeconomically disadvantaged groups appearing to benefit more from available social ties (Cao et al., 2022). Complementary findings indicate that community social capital interacts with individual vulnerabilities (e.g., functional limitations or smoking) in shaping self-rated health, highlighting its role as a contextual moderator beyond a direct main effect on health (Sun & Lu, 2025). Moreover, a systematic review of social capital interventions targeting older people suggests that enhancing participation, trust, and cohesion can improve quality of life and self-perceived health, underscoring the modifiable nature of social capital even if effects on mood remain inconsistent (Coll-Planas et al., 2016). However, despite the evidence, relatively few studies have explicitly examined whether neighborhood social capital moderates the relationship between objectively measured spatial resource accessibility and inequality and depressive symptoms in later life.

2.4. Theoretical framework

The above-reviewed literature provides the theoretical and empirical foundation for the present study. By synthesizing P–E fit theory (Lawton & Nahemow, 1973), the spatial inequality perspective (Noll & Bhar, 2023; Wei, 2015), and social capital theory (Putnam, 2001), we adopt a multidimensional approach that focuses on both the absolute and distributional aspects of spatial resource accessibility and examines how these structural features interact with community social capital to shape mental health in later life (see Fig. 1). Specifically, P–E fit theory highlights the importance of aligning individuals' needs and abilities with the provisions and demands of their surrounding environments, suggesting that the resource accessibility can significantly influence well-being. The spatial inequality perspective draws attention to the uneven distribution of resources across different geographic areas, emphasizing both absolute levels and disparities in accessibility. Social capital theory underscores the protective role of community networks, trust, and social cohesion for mental health. Three key hypotheses are proposed:

H1. Higher levels of spatial accessibility to age-relevant resources are associated with lower depressive symptoms among older adults.

H2. Greater inequality in spatial accessibility to resources is associated with higher depressive symptoms among older adults.

H3. Community social capital buffers the associations between both absolute accessibility and distributional inequality in spatial resource and depressive symptoms among older adults.

3. Method

3.1. Study area and data

This study was conducted in Hong Kong, one of the most densely populated and highly urbanized regions in the world, with a population of approximately 7.4 million residing in a total land area of just over 1100 km^2. Hong Kong is characterized by stark socioeconomic disparities and heterogeneous distributions of urban services, making it a critical context for examining spatial inequalities in health outcomes. The city's compact urban form, high-rise residential developments, and fragmented distribution of green and community services create a unique setting for studying how accessibility and equity of urban resources affect older adults' mental health. Fig. 2 shows the spatial distribution of the older population in the study area.

We utilized individual-level data from the baseline wave of the Panel Study of Active Ageing and Society (PAAS), a biennial, population-representative survey of adults aged 50 years and older residing in Hong Kong. The PAAS was designed to examine the social, economic, and environmental determinants of active ageing in a high-density urban context. Data collection for the baseline wave took place between June and November 2022 and employed a dual-frame random-digit-dialing approach, covering both landline and mobile phone numbers. The sample was stratified by age (50–64 vs. 65+) with target proportions for age–sex–district strata based on the 2021 Population Census. Eligible respondents were community-dwelling adults aged 50 and above, cognitively capable of completing the questionnaire and able to communicate in Cantonese. The final sample included 5007 respondents, yielding a response rate of 60.3 %. Post-stratification weights incorporating age, sex and district were constructed so that the weighted sample reproduces the joint population distribution of older adults across these strata; these individual-level survey weights were applied in all descriptive and regression analyses. All respondents provided informed consent, and the study was approved by the institutional ethics committee of the host university.

To construct district-level measures of accessibility and inequality in urban resources, we integrated individual-level PAAS survey data with secondary geospatial data from the Common Spatial Data Infrastructure (CSDI), an official platform that provides detailed spatial information on population census data as well as the locations of parks, healthcare

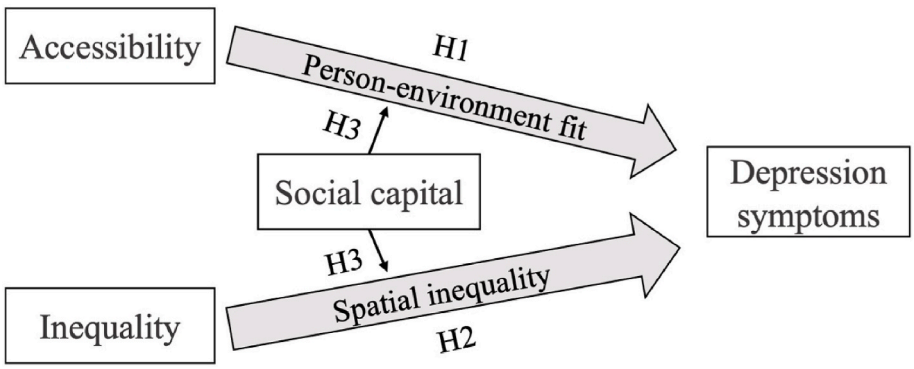

Fig. 1. Theoretical framework.

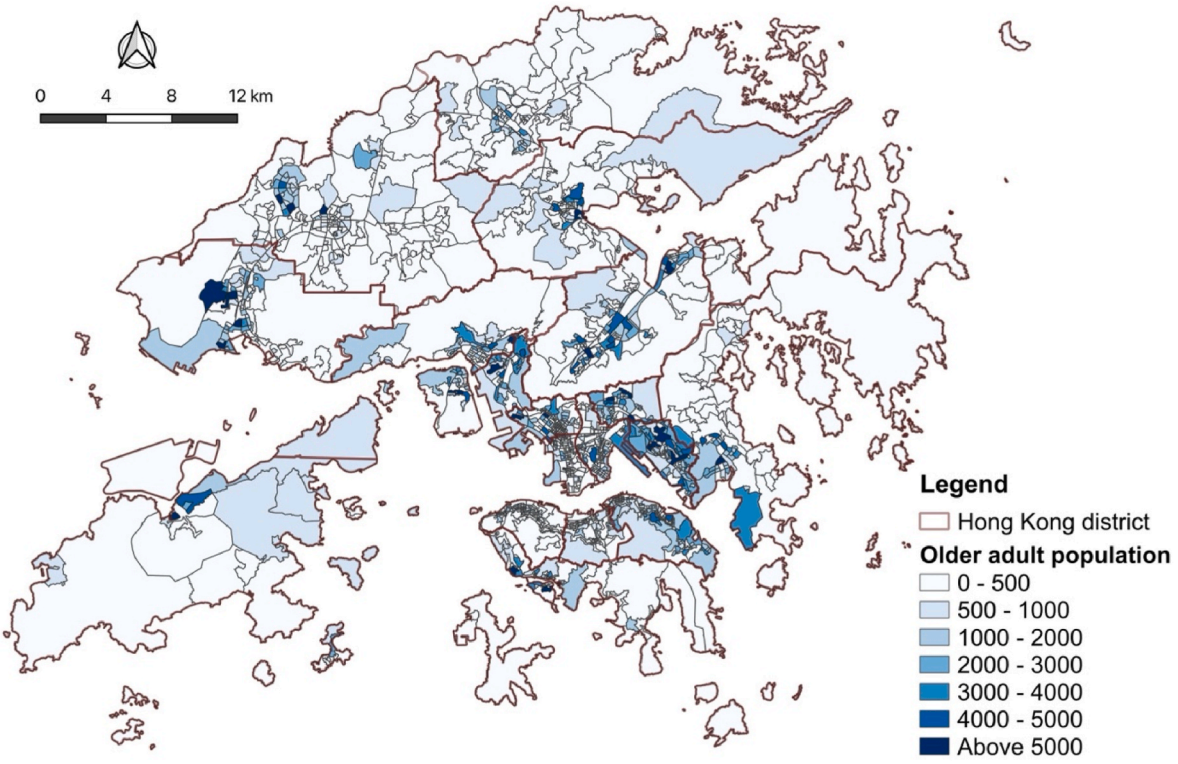

Fig. 2. Study area.

facilities, public transportation nodes, and elderly service centers. Large Subunit Group (LSUG) is the smallest geographical unit where census data are available in Hong Kong. We first calculated accessibility scores at 1746 LSUGs level using an exponential distance-decay function and weighted them by the local older adult population. These LSUG-level scores were then aggregated to the district level to produce two indicators: absolute accessibility and within-district inequality (measured by the Gini coefficient of LSUG scores within each district). Finally, these district-level indicators were merged with individual data for subsequent analysis.

3.2. Measures

3.2.1. Depressive symptoms

The primary outcome was depressive symptoms, assessed using the 8-item Center for Epidemiologic Studies Depression Scale (CES-D-8), a widely validated screening instrument for depressive symptomatology in community and older adult populations (Wang et al., 2017). The CES-D-8 captures the frequency of depressive symptoms experienced in the past week, including feelings of loneliness, sadness, restless sleep, and lack of motivation. Responses are scored on a four-point Likert scale (1 = rarely or none of the time to 4 = most or all of the time), yielding a total score ranging from 8 to 32, with higher scores indicating more severe depressive symptoms. The CES-D-8 has demonstrated good reliability and validity in prior studies of older adults in both Western and Asian contexts (Jiang et al., 2024; Karim et al., 2015), making it suitable for application in Hong Kong.

3.2.2. Independent variables: resource access and inequality

Two dimensions of the urban resource environment were examined: absolute accessibility and resource inequality, both measured at the district level. Specifically, we focus on four types of urban facilities that are closely related to older adults' wellbeing: parks and open spaces, public transport facilities, healthcare facilities, and elderly service facilities (Garrett et al., 2019; Hemalatha et al., 2023; Wang et al., 2025). The specific facilities under each type can be found in Table S1 in the Appendix. To capture neighborhood-level differences in access to city-wide infrastructure, we employed an exponential distance-decay model that accounts for declining accessibility with increasing distance. This approach emphasizes spatial opportunity rather than service sufficiency (Tu et al., 2025). Aligning well with our research objective, this approach allows us to evaluate how accessible citywide facilities are from the standpoint of each neighborhood, rather than being limited to predefined local catchment areas.

District-level accessibility was derived from LSUG-level accessibility scores based on an exponential distance-decay function applied to network-based distances:

$$Access_i = \sum_{j=1}^{n} \left(e^{-\alpha d_{ij}}\right)$$

where $Access_i$ is the accessibility score for LSUG i, d_{ij} is the shortest-path distance along the street network between LSUG i and facility j, and $\alpha = 0.001$ represents distance sensitivity in a dense urban context (Sevtsuk & Kalvo, 2018). This continuous method avoids arbitrary catchment boundaries and offers a more refined estimation of access, particularly in compact cities with overlapping service areas.

To account for the spatial distribution of older residents, LSUG accessibility scores were population-weighted by the share of adults aged 65+ in each LSUG and then aggregated to the district level. This ensures that LSUGs with larger older populations contribute more to the district accessibility score:

$$W_i = A_i \times \frac{P_i}{P_k}$$

where A_i is the raw accessibility score for LSUG i, P_i the population aged 65 and above in LSUG i, and P_k is the population aged 65 and above in Hong Kong.

Within-district inequality in access was quantified using the Gini coefficient calculated across LSUG-level access scores. Each LSUG

contributed equally to the district Gini, which primarily captures LSUG-based spatial inequality. This measure of spatial inequality complements the absolute accessibility indicator and allows us to assess how uneven access to citywide resources may shape environmental determinants of well-being (Rigolon, 2016).

3.2.3. Moderator: social capital

We measured neighborhood social capital using three survey items that capture residents' perceptions of helpfulness, trust, and belonging: "Neighbors are willing to help each other", "I can trust people living here", and "I feel a sense of belonging to this community". Each item was rated on a 5-point Likert scale (1 = strongly disagree to 5 = strongly agree), and responses were summed to form a composite score (range 3–15), with higher scores indicating higher neighborhood social capital. This brief scale is consistent with commonly used measures of cognitive social capital in Chinese community-health research (Sun & Lu, 2025). Internal consistency in our sample was good (Cronbach's $\alpha = 0.825$).

3.2.4. Covariates

A comprehensive set of individual-level covariates was included to adjust for potential confounders, based on established determinants of late-life depression identified in prior research. Socio-demographic characteristics encompassed age, gender, marital status, educational attainment, employment status, household income, and self-rated socioeconomic status (Meyer et al., 2014). Health-related and behavioral factors included self-rated health, number of chronic conditions, medical insurance coverage, smoking status, alcohol consumption, and engagement in physical activity (Pengpid & Peltzer, 2023). Social dimensions were captured through measures of social participation, including both the diversity of activities and the frequency of engagement across different domains of social activities (SA). The sample characteristics can be found in Table 1.

3.3. Modeling approach

We estimated single-level linear regression models with district fixed effects to examine factors associated with depressive symptom, applying the age–sex–district post-stratification weights to obtain population-representative estimates. This approach was chosen because the intra-class correlation coefficient (ICC) for depressive symptoms was very low (ICC = 0.01), indicating minimal between-district variance; the number of level-2 units was small (18 districts), limiting the reliability of random-effects estimation; and district fixed effects (district dummies) allow us to control for unobserved district heterogeneity while retaining a straightforward interpretation of individual-level coefficients (Dong et al., 2020; Maas & Hox, 2005; Sommet & Morselli, 2021).

As for the statistical analysis, we first conducted principal component analysis (PCA) on eight resource-related indicators covering both accessibility and inequality dimensions across parks, transportation, healthcare, and elderly service facilities to reduce dimensionality and avoid multicollinearity. Two principal components were extracted: RI representing resource access inequality, and RA capturing overall resource accessibility. These components were then appended to the main analytic dataset as key contextual predictors.

Model 1 regressed depressive symptoms on RA, RI, individual socio-demographic, health and psychosocial covariates, and district fixed effects, using population sampling weights. Model 2 added interactions between social capital and RA/RI to test whether neighborhood social capital moderates the effects of accessibility and inequality; interaction plots were produced to visualize these effects. We further estimated separate models by gender and housing tenure (public vs. private) to explore subgroup heterogeneity. Standardized coefficients (β) are reported for all models. Finally, we examined spatial autocorrelation in the residuals using Moran's I; the statistic was small and non-significant ($I = 0.069$, $p = 0.165$), indicating no evidence of residual spatial clustering. All regression models were estimated using the "lm" function in R version 4.5.0, and both standardized and unstandardized coefficients were extracted. A diagnostic check of multicollinearity (via VIF) was conducted to validate model assumptions.

As robustness checks, we re-estimated all models using alternative specifications of the contextual measures: network-based accessibility and Gini coefficients with $\alpha = 0.002$, and Euclidean-distance-based accessibility and inequality with $\alpha = 0.001$ and $\alpha = 0.002$. The

Table 1
Weighted and unweighted descriptive information for key variables (N = 5007).

Variable	Category	Unweighted	Weighted
		Mean ± SD/ Number (%)	Mean ± SD/ Number (%)
CESD-8		13.19 ± 3.63	13.27 ± 3.70
Age		64.22 ± 8.35	64.10 ± 9.30
Gender	Male	2328 (46.5 %)	2328 (46.5 %)
	Female	2679 (53.5 %)	2679 (53.5 %)
Marriage	Singel, divorced, widowed and other	1386 (27.7 %)	1461.13 (29.2 %)
	Married and co-living	3621 (72.3 %)	3545.87 (70.8 %)
Education	Below high school	2689 (53.7 %)	2620.74 (52.3 %)
	Highschool and above	2318 (46.3 %)	2386.26 (47.7 %)
Live with son/ daughter (in-law)	No	2424 (48.4 %)	2412.64 (48.2 %)
	Yes	2583 (51.6 %)	2594.36 (51.8 %)
Live along	No	4234 (84.6 %)	4222.54 (84.3 %)
	Yes	773 (15.4 %)	784.46 (15.7 %)
Employment status	Other	3121 (62.3 %)	3179.70 (63.5 %)
	Retired	1886 (37.7 %)	1827.30 (36.5 %)
Housing type	Public/subsidized housing	3329 (66.5 %)	3297.01 (65.8 %)
	Private estate and other	1678 (33.5 %)	1709.99 (34.2 %)
Household monthly income	Below 30,000 HKD	2589 (51.7 %)	2517.36 (50.3 %)
	30,000 HKD and above	2418 (48.3 %)	2489.64 (49.7 %)
Medical insurance	No	3755 (75.0 %)	3717.45 (74.2 %)
	Yes	1252 (25.0 %)	1289.55 (25.8 %)
Self-report SES		2.26 ± 0.84	2.20 ± 0.69
Smoking	No	4362 (87.1 %)	4369.91(87.3 %)
	Yes	645 (12.9 %)	637.09 (12.7 %)
Drinking	No	3859 (77.1 %)	3887.16 (77.6 %)
	Yes	1148 (22.9 %)	1119.84 (22.4 %)
PA in past 30 days	No	3725 (74.4 %)	3735.67 (74.6 %)
	Yes	1282 (25.6 %)	1271.33 (25.4 %)
Number of chronic diseases		0.97 ± 1.07	0.97 ± 1.09
Self-reported health		2.22 ± 0.68	2.22 ± 0.68
Types of SA		8.26 ± 2.84	8.26 ± 2.87
Leisure and socializing SA		1.08 ± 0.35	1.08 ± 0.36
Productive SA		0.08 ± 0.12	0.08 ± 0.12
Social capital		10.64 ± 2.15	10.65 ± 2.13
Access inequality of parks and open spaces		0.57 ± 0.12	0.56 ± 0.12
Access inequality of public transport facilities		0.56 ± 0.11	0.55 ± 0.12
Access inequality of healthcare facilities		0.58 ± 0.12	0.57 ± 0.13
Access inequality of elderly service facilities		0.60 ± 0.12	0.59 ± 0.13
Accessibility of parks and open spaces		0.44 ± 0.23	0.46 ± 0.24
Accessibility of public transport facilities		7.12 ± 4.74	7.47 ± 4.81
Accessibility of healthcare facilities		0.34 ± 0.31	0.36 ± 0.32
Accessibility of elderly service facilities		0.25 ± 0.16	0.26 ± 0.16

substantive findings were unchanged (Table S2–S3), and the resulting accessibility and inequality indicators for all specifications are reported in Table S4.

4. Results

4.1. Spatial patterns of access inequality

Fig. 3 maps within-district inequality in access to the four facility types, measured by Gini coefficients ranging from about 0.2 to 0.9. Across all services, the Islands District (ILD) consistently falls in the highest inequality class (0.8–0.9), indicating a very uneven distribution of age-friendly infrastructures within the district. The exceptionally high inequality in the Islands District likely reflects its distinctive heterogeneous settlement and connectivity structure. Population and services are highly concentrated in Tung Chung New Town, while the remainder are dispersed across rural Lantau and multiple outlying islands. Because many communities are ferry-reliant rather than embedded in the road/rail network, accessibility can be extremely uneven across LSUGs within the district, mechanically inflating the Gini coefficient. Several peripheral New Territories districts (such as Yuen Long and Tai Po) also show comparatively high inequality, particularly for healthcare and elderly services, whereas the inner-urban districts on Hong Kong Island and in Kowloon (such as Central and Western, Wan Chai, and Yau Tsim Mong) generally lie in the lowest inequality bands (<0.4), suggesting relatively even intra-district access. Public transport facilities with the lowest average Gini coefficient appear more evenly distributed than other resources overall, but still exhibit marked inequality in the Islands District. These spatial contrasts highlight a clear core-periphery gradient: older residents in central urban districts experience more equitable access to age-relevant infrastructure, while those in outlying districts live in settings where resources are concentrated in a few better-served neighborhoods.

4.2. PCA results

To reduce multicollinearity and derive composite indicators for modeling, a PCA was conducted on eight spatial variables reflecting the inequality (RI) and accessibility (RA) of four types of resources: parks and open spaces, public transport facilities, healthcare facilities, and elderly service facilities (see Table 2). Two principal components were

Table 2
Factor loading of the PCA.

Variable	RI	RA
Access inequality of parks and open spaces	0.962	−0.232
Access inequality of public transport facilities	0.961	−0.189
Access inequality of healthcare facilities	0.917	−0.342
Access inequality of elderly service facilities	0.934	−0.320
Accessibility of parks and open spaces	−0.291	0.928
Accessibility of public transport facilities	−0.331	0.945
Accessibility of healthcare facilities	−0.689	0.439
Accessibility of elderly service facilities	−0.237	0.957
Explained variance	0.536	0.400

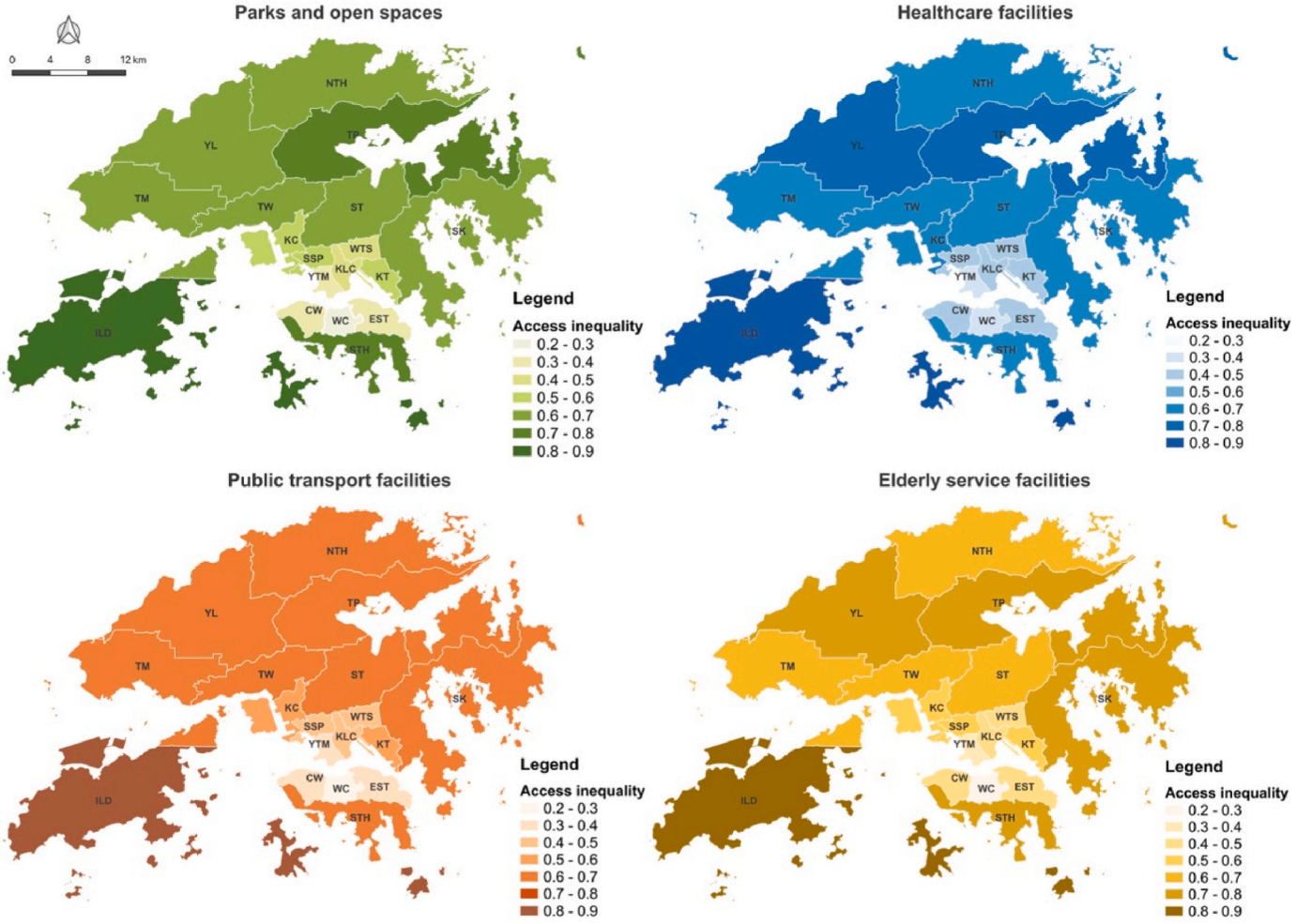

Fig. 3. Access inequality to resources across Hong Kong.

extracted based on eigenvalues greater than 1 and varimax rotation. Together, these components explained 93.6 % of the total variance. All factor loadings exceeded 0.4 in absolute value, indicating strong and interpretable associations between the original variables and the extracted components (Hair Jr et al., 2010).

4.3. Regression results

Table 3 reports the results of the baseline linear regression model predicting depressive symptoms. After adjusting for individual socio-demographic, health, behavioral, social, and contextual covariates, both resource inequality (RI) and accessibility (RA) exhibited significant associations with depressive symptoms. Specifically, higher resource inequality was associated with greater depressive symptoms ($\beta = 0.129$, $p < 0.001$), while higher accessibility was associated with lower depressive symptoms ($\beta = -0.389$, $p < 0.001$). Among covariates, neighborhood social capital, self-rated health, medical insurance, and leisure and social interaction activities were all negatively associated with depressive. In contrast, living alone and the number of chronic conditions were positively associated with more symptoms.

In Model 2, we examined whether neighborhood social capital moderated the associations between the two spatial resource indicators and depressive symptoms. Social capital was entered as a continuous, mean-centered variable, and its interactions with resource access inequality and overall resource accessibility were included. A significant interaction was observed between resource inequality and social capital ($\beta = -0.035$, $p < 0.01$), indicating that high social capital mitigated the adverse effect of resource inequality on depressive symptoms. Fig. 4 illustrates the moderating effect of social capital on the association between resource inequality and depressive symptoms. No significant interaction was detected between resource accessibility and social capital.

Table 3
Linear regression results on depressive symptoms.

Variables	Model 1		Model 2	
	Std_Beta	Sig	Std_Beta	Sig
(Intercept)	−0.182	***	−0.197	***
Age	−0.022		−0.021	
Female	0.062	*	0.063	*
Married and co-living	−0.163	***	−0.162	***
Education: Highschool and above	−0.014		−0.014	
Live with son/daughter	−0.026		−0.024	
Live alone	0.178	***	0.180	***
Retired	−0.041	*	−0.042	*
Residential type (Private estate)	0.007		0.009	
Household income above 30000/month	−0.048		−0.048	
Self-rated SES	−0.067	***	−0.068	***
Medical insurance (yes)	−0.319	***	−0.318	***
Smoking (yes)	0.065		0.063	
Drinking (yes)	0.119	***	0.121	***
Physical activity (yes)	−0.049		−0.049	.
Types of SA	0.148	***	0.150	***
Leisure and socializing SA	−0.139	***	−0.141	***
Productive SA	0.043	*	0.043	*
Number of chronic diseases	0.105	***	0.104	***
Neighborhood social capital	−0.196	***	−0.197	***
Self-rated health	−0.203	***	−0.203	***
Access inequality (Gini)	0.129	***	0.140	***
Accessibility score	−0.389	***	−0.412	***
Access inequality (Gini) * Social capital			−0.035	**
Accessibility score * Social capital			0.005	
Fixed effect of districts	Controlled		Controlled	
R^2	0.242		0.243	
Adjusted R^2	0.237		0.238	

Note: "*": Significant at 0.05; "**": Significant at 0.01; "***": Significant at 0.001.

4.4. Heterogeneity analyses

Table 4 presents the results stratified by gender and housing type. The associations of both resource inequality and accessibility with depressive symptoms were significant across all groups. The buffering role of social capital on resource inequality, however, was found to be significant only for women and people living in public/subsidized housing estates.

5. Discussion

5.1. *Resource inequality and depressive* symptoms

This study provides robust evidence that higher spatial inequality in resource accessibility, as measured by Gini coefficients, is consistently associated with greater depressive symptoms among older adults. This finding underscores that it is not only the absolute amount of resources available but also their equitable distribution that shapes mental well-being. Access inequality of parks and open spaces, healthcare, transport, and elderly services may foster perceptions of inequality, frustration, and relative deprivation, which are linked to psychological distress. The findings remained robust in subgroup analyses and when we re-estimated the models using alternative accessibility and inequality measures based on network- and Euclidean-distance calculations with different decay parameters ($\alpha = 0.001$ and 0.002). This indicates that the mental health consequences of spatial inequality are broadly experienced among older adults, regardless of their demographic or housing status. The consistency of effects across these subgroups implies that inequitable environments may function as a structural stressor that transcends individual-level vulnerabilities, highlighting the systemic nature of spatial inequality in urban aging contexts (Song et al., 2024).

Viewed through an urban justice lens, these results suggest that cities failed in distributive justice in the local opportunities might threaten older adults' mental health, even after accounting for average accessibility (Noll & Bhar, 2023). This pattern echoes broader evidence that structural inequalities, whether in income or in the distribution of services, are associated with poorer population mental health and greater psychological distress (Kondo et al., 2009; Muramatsu, 2003). As such, inequitable environments may act as chronic stressors, compounding the effects of aging and limiting access to health-enhancing infrastructure (Gelormino et al., 2015). Our findings therefore extend the P–E fit frameworks (Lawton & Nahemow, 1973), highlighting that structural inequalities embedded in the built environment contribute to health disparities beyond the (mis)fit between personal competence and environmental press. Built environments embedded with inequities can reinforce structural disadvantage (Tu et al., 2025), particularly for older adults who experience declining mobility and reduced adaptive capacity.

By linking spatial inequality in resource accessibility with mental health outcomes, this study contributes to the emerging discourse on structural determinants of mental health within urban aging research. It complements prior research, such as Wei et al. (2024), which demonstrated that exposure to peri-urban park greenery was associated with reduced years of life lost in Hong Kong, but did not assess the role of inequality in such exposure. Both our study and prior findings suggest a twofold dynamic in resource accessibility: while absolute resource exposure supports mental health, access inequality may negate or even reverse those benefits for mental health.

5.2. Resource accessibility and depressive symptoms

In line with previous research, our results demonstrate that greater accessibility to age-relevant urban resources such as parks and open spaces, transport, healthcare facilities, and elderly service centers is significantly associated with lower depressive symptom levels among older adults. This reinforces the importance of the social determinants of

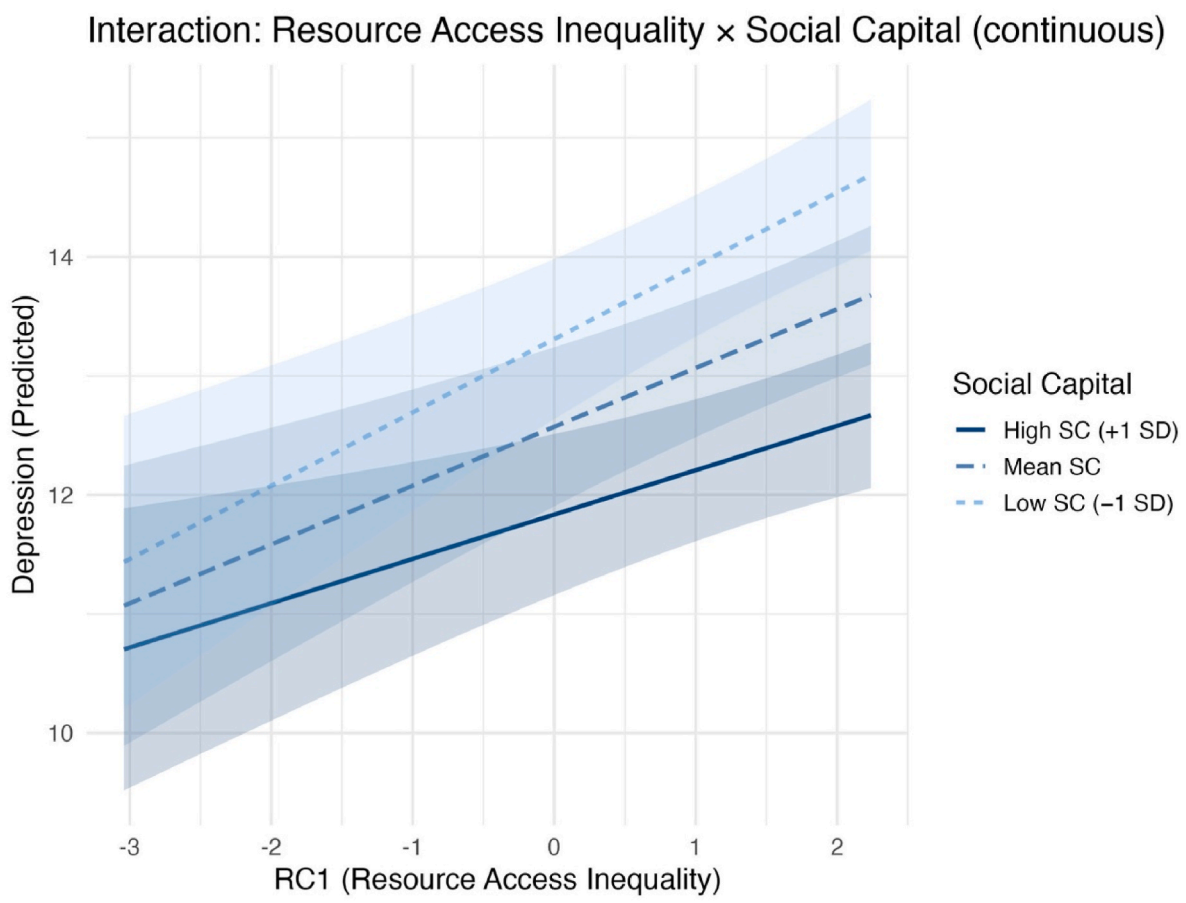

Fig. 4. Interaction between resource access inequality and social capital.

Table 4
Heterogeneity test by gender and housing type.

Parameter	Male		Female		Public and subsidized Housing		Private Estates	
	Std_Beta	Sig	Std_Beta	Sig	Std_Beta	Sig	Std_Beta	Sig
Access inequality (Gini)	0.158	**	0.132	**	0.120	**	0.183	*
Accessibility score	−0.491	**	−0.356	**	−0.473	**	−0.342	*
Access inequality (Gini) * Social capital	−0.035		−0.039	*	−0.034	*	−0.027	
Accessibility score * Social capital	−0.009		0.018		−0.003		0.017	
R^2	0.248		0.250		0.233		0.289	
Adjusted R^2	0.236		0.239		0.224		0.272	

Note: "*": Significant at 0.05; "**": Significant at 0.01; "***": Significant at 0.001.

health framework and the environmental affordance perspective, both of which stress the role of accessible built environments in promoting opportunities for physical activity, social interaction, and reduced stress (Diez Roux & Mair, 2010). It should be noted that healthcare accessibility contributed less strongly to the composite accessibility dimension than other amenities (RA loading = 0.439). This likely reflects Hong Kong's hierarchical, cluster-based public healthcare planning, in which service catchment areas are delineated around major acute hospitals and specialist services that intentionally serve broad populations, rather than a limitation of the accessibility measure itself (Legislative Council, 2025).

Our findings align with international evidence that parks and green spaces enhance psychological well-being by providing restorative environments and opportunities for social connection, and that accessible transport and healthcare reduce anxiety over mobility and care needs in later life (Maas et al., 2009; Musselwhite et al., 2015). Recent Hong Kong studies similarly show that older adults' mental health benefits from better access to urban greenery and amenities, and that neighborhood form shapes distress partly through perceived accessibility (Liu et al., 2024; Ma & Yang, 2024). These results point out the importance of planning interventions that improve not only the quantity but also the accessibility of resources to ensure that older residents can benefit from supportive environments.

5.3. *Buffering role of social capital*

Another key contribution of this study is the identification of a moderating role of neighborhood social capital. Higher social capital attenuated the association between resource inequality and depressive symptoms but did not significantly modify the association between average accessibility and depressive symptoms, suggesting that social capital may be particularly important for helping older adults navigate uneven environments rather than uniformly resource-poor ones. This supports the stress-buffering hypothesis, which posits that strong social

networks, trust, and mutual support can cushion individuals from environmental stressors and adversity (Cohen & Wills, 1985). Our findings are consistent with previous evidence showing that social cohesion and trust are critical psychosocial resources, particularly in disadvantaged settings (Cao et al., 2022; Chen et al., 2021). In neighborhoods with unequal resources, strong community ties may facilitate informal support, shared use of scarce resources, and collective coping, thereby preserving mental health even in structurally challenging environments. By contrast, when the district has low accessibility, even strong community ties cannot substitute for the absence of essential urban infrastructures. Stress-buffering theory views social support as a moderator of the psychological impact of stressors rather than a mechanism that removes exposure to those stressors, so its protective effect is inherently constrained when material deprivation is severe and persistent (Cohen & Wills, 1985). Consistent with this, reviews of social capital and health conclude that while neighborhood social capital can mitigate some health inequalities, its effects are partial and strongly contingent on broader structural conditions such as income and service provision (Uphoff et al., 2013). In addition, evidence from Hong Kong have shown that community social capital captured by older adults' sense of community and perceived cohesion, often mediates the relationship between age-friendly features and mental well-being (Guo et al., 2021), suggesting that social capital may more commonly operate as a pathway linking accessibility to mental health rather than as a universal moderator.

Furthermore, the heterogeneity analysis indicates that the moderating role of neighborhood social capital is context-dependent, being evident primarily among females and residents of public/subsidized housing. This aligns with evidence that neighborhood social and environmental conditions can operate through gender-differentiated pathways to depressive symptoms, with women in some contexts showing greater sensitivity to community-level resources and a stronger mental-health benefit from social capital (Bassett & Moore, 2013). Regarding housing tenure, Hong Kong public/subsidized estates are intentionally planned and managed with shared common areas and ancillary facilities to promote social interaction and neighborliness. By contrast, many private estates feature more privatized or segmented interaction spaces and comparatively weaker estate-level social programming, which may limit the translation of perceived cohesion into actionable support or neighbor interaction in Hong Kong's high-rise contexts (Chan et al., 2008).

Taken together, these perspectives suggest that social capital and urban infrastructure are complementary rather than interchangeable determinants of mental health, and our findings reinforce the importance of improving both absolute accessibility and the equity of resource distribution for promoting late-life mental well-being.

5.4. Policy and planning implications

Our findings suggest that age-friendly planning in high-density cities like Hong Kong should move beyond aggregate service ratios to explicitly incorporate distributional justice. The Hong Kong Planning Standards and Guidelines (HKPSG) largely rely on population-based ratios, such as a minimum of 2 m^2 of public open space per person in urban areas and territory-wide planning ratios for elderly services. According to our findings, these city-wide benchmarks should be complemented by equity metrics, for example, by incorporating accessibility and Gini-type inequality indicators into routine HKPSG audits and using them to prioritize the siting or upgrading of age-friendly infrastructures in districts and LSUGs with the greatest access shortfalls, rather than only meeting average per-capita targets.

Our findings highlight the protective role of community social capital for older residents' mental health. To enhance neighborhood trust, social networks, and community social capital, policymakers, urban planners, and property developers should consider prioritizing accessible, safe, and multifunctional public spaces that promote social interaction, particularly in private estates, where semi-public areas are often more privatized, tightly managed, or fragmented. Thoughtful design and meaningful community engagement, combined with community-building programs and participatory planning, can foster belonging, strengthen social ties, and provide older residents with vital psychosocial resources, thereby advancing both social capital and distributional justice within the community and enhancing mental health.

5.5. Limitations

This study has several limitations that warrant consideration. First, the cross-sectional design of the analysis precludes causal inference; while associations between resource environments, social capital, and depressive symptoms are identified, the temporal direction of these relationships cannot be definitively established. Longitudinal research is needed to clarify causal pathways and to examine how changes in accessibility and inequality over time influence mental health trajectories in later life. Second, our analysis relies solely on objective indicators of accessibility and within-district inequality. These measures capture the structural distribution of urban resources but not older adults' subjective perceptions of accessibility, fairness, or neighborhood quality, which may independently shape mental well-being. Future work should incorporate perceived accessibility, perceived neighborhood justice, and qualitative accounts of lived experience to link structural patterns with subjective appraisals. Finally, accessibility was originally calculated at the LSUG level and then aggregated to the 18 administrative districts, which may introduce Modifiable Areal Unit Problem (MAUP)-related bias and obscure within-district heterogeneity. We adopted the district as the contextual unit because the PAAS survey was stratified and weighted to be representative at the district level, and districts are the primary planning unit for allocating elderly services in Hong Kong. Nevertheless, future studies should explore multi-scale or multi-level designs that relate individual outcomes to resource patterns at finer spatial units.

6. Conclusion

This study contributes to a growing body of evidence highlighting the importance of equitable urban resource environments for promoting mental well-being among older adults. By simultaneously examining absolute accessibility, spatial inequality, and the moderating role of social capital, our findings extend the theoretical and empirical understanding of how structural and social determinants intersect to shape late-life depressive symptoms. We demonstrate that not only the availability of urban resources, but also the equity of their distribution across neighborhoods, are critical for older residents' mental health. Furthermore, the buffering role of neighborhood social capital underscores the potential of strengthening social cohesion as a complementary strategy to mitigate the adverse effects of environmental inequities.

These findings carry important implications for urban planning and policy. Efforts to foster age-friendly and just cities should prioritize reducing intra-urban disparities in resource access while enhancing social environments, particularly in socioeconomically disadvantaged areas such as public housing estates. As global urban populations continue to age, ensuring both equitable spatial accessibility and strong social fabric will be essential to supporting mental health and well-being in later life. Future research integrating longitudinal, spatial, and multilevel perspectives can further advance knowledge and inform policies aimed at creating healthier, more inclusive urban environments for aging societies.

CRediT authorship contribution statement

Min Yang: Writing – review & editing, Writing – original draft, Methodology, Funding acquisition, Formal analysis, Conceptualization.

Xue Bai: Writing – review & editing, Supervision, Resources, Funding acquisition. **Yuxuan Zou:** Writing – review & editing, Validation, Methodology, Data curation.

Ethical approval

All study procedures and protocols of this non-clinical study involving human subjects were approved by the institutional review board of the first author's affiliated University (Reference Number: HSEARS20220517001).

Declaration of generative AI and AI-assisted technologies in the writing process

Statement: During the preparation of this work the authors used ChatGPT 4.0 in order to assist with English language improvement. After using this tool, the authors reviewed and edited the content as needed and take full responsibility for the content of the published article.

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Declaration of competing interest

The authors declare no competing interests.

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Appendix A. Supplementary data

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